On National e-Healthcare Delivery Through Nigcomsat-1

Felix N. C. Anyaegbunam

Department of Physics/Geology/Geophisics,
Federal UniversityNdufu-Alike-Ikwo, Abakaliki, Ebonyi State, Nigeria

Abstract

NIGCOMSAT-1 is a geo-stationary communication satellite recently launched by National Space Research and Development Agency (NARSDA) of Nigeria in collaboration with the China Great wall Industries. Amongst the various benefits of NIGCOMSAT-1, the most important applications that will directly affect the lives of ordinary Nigerians are probably in Healthcare delivery. Nigcomsat-1 provides efficient medium for transmitting heavy streaming video and audio signals required in Telemedicine, as well as transmitting bio-signals and patient images from the telemedicine centres to the base stations. These processes require large bandwidth carriers with HDR transmission such as fibre optics or satellites.This paper outlines the basic principles of NIGCOMSAT-1 and discusses how its deliverables would be beneficial to national healthcare delivery in Nigeria. The strategies for the provision of effective emergency healthcare and home monitoring solutions facilitated by Nigcomsat-1 are the major interests discussed in this paper. Ambulances, Rural Health Centres (RHC)or other remote health locations such as Ships navigating in wide seas are common examples of possible emergency sites, while critical care telemetry and home follow-ups are important issues of tele-monitoring.
Keywords: Nigcomsat-1, healthcare delivery, telemedicine, communications satellite.

1. INTRODUCTION

1.1. Geosynchronous Satellites

The first thirty years of growth and development of geosynchronous satellites has provided the world with international and long distance fixed satellite services (FSS) that have helped, in large measure, to create the Marshall McLuhan vision of the global electronic village. It has even been said that satellites have become the greatest force for the "super-tribalization" of the human species - even more important than television [3]. Starting with the global viewing of the moon landing in July 1969, communications satellites have changed the world.

The National Space Research and Development Agency (NARSDA) of the Federal Ministry of Science and Technology, in collaboration with the China Great wall Industry Corporation, recently launched the first Nigeria's Communications Satellite (NIGCOMSAT-1) into the geosynchronous orbit. it is a super hybrid geo-stationary satellite designed to operate in C, Ku, Ka and L bands with footprints over Africa, part of Middle East and southern Europe. [4]

1.2 HEALTHCARE DELIVERY

Telemedicine is one of the pilot projects of NIGCOMSAT-1 with an objective to develop a telemedicine system to improve remote diagnosis and to deliver cost effective, better quality specialists healthcare in Nigeria. Telemedicine is defined as the delivery of health care and sharing of medical knowledge over a distance using telecommunication means. Thus, the aim of Telemedicine is to provide expert-based health care to understaffed remote sites and to provide advanced emergency care through modern telecommunication and information technologies.

It has been observed [1] that the benefits gained from applying information and communications technology in a wider and more comprehensive manner from the management of healthcare to its delivery could be truly enormous. If there exists a more integrated flow of medical information, plus instant access to relevant data, healthcare planners could eliminate many of the redundancies in the system, cutting costs and improving efficiencies all round [1]. According to [3] the vision for e-healthcare promises far more than just financial savings. The unwieldy bureaucracy behind most of today's healthcare systems is responsible for not only runaway costs, but also a lot of bad medicine. Unnecessary duplication and ignorance of the latest medical procedures contribute substantially to current levels of sickness and death.

E-healthcare involves the use of very high rates of data transmission (up to 155 megabits/s) in applications requiring real-time, high-speed, wide-bandwidth transmission modes such as cardiac catheterization, echocardiography, and telemedicine consultations using multimodality imaging techniques for assessment of patients with congenital heart disease. Today, e-Healthcare systems are supported by State of the Art Technologies like Interactive video, high resolution monitors, high speed computer networks, switching systems, and telecommunications superhighways including fibre optics, satellites and cellular telephony [6],[2],[5].

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In a study performed in the UK in 1998 [13], it is sobering to see that among patients above 55 years old, who die from cardiac arrest, 91% do so outside hospital, due to a lack of immediate treatment. In cases where thrombolysis is required, survival is related to the "call to needle" time, which should be less than 60 minutes [14]. Thus, time is the enemy in the acute treatment of heart attack or sudden cardiac death (SCD). In Nigeria, many avoidable deaths occur in rural locations due to lack of access to medical facilities and expertise. Many studies worldwide have proven that a rapid response time in pre-hospital settings resulting from treatment of acute cardiac events decreases mortality and improves patient outcomes dramatically [15]-[20]. In addition, other studies have shown that 12-lead ECG performed during transportation increase available time to perform thrombolytic therapy effectively, thus preventing death and maintaining heart muscle function [21]. The reduction of all those high death rates is definitely achievable through strategies and measures, which improve access to care, administration of pre-hospital care and patient monitoring techniques facilitated by Satellite mediated Telemedicine or electronic healthcare delivery.

2. NIGERIAN COMMUNICATIONS STATELLITE (NIGCOMSAT-1)

2.1. BackgroundonCommunications Satellites

Two types of Earth orbiting satellites are used in Communications today – they are: a) Low-Earth-Orbiting Satellites (LEO) which orbit at about 400 miles or less from the Earth with a period of about 90 minutes; b) Geosynchronous or Geostationary Satellites (GEO) which orbit at about 22,300 miles from the Earth with a period of 24 hours.

The first artificial Satellite (LEO) called Sputnick was launched by Soviet Union in 1957 and was just a little spherical case with a radio transmitter and a period of 90 minutes. This means that although people anywhere on earth will eventually see it, the Satellite may not be viewed for more than 10 minutes at a time before it disappears. However, Arthur Clarke had earlier pointed out in the mid-1940s that a satellite orbiting at an altitude of 22,300 miles would require exactly 24 hours to orbit the earth. Hence such an orbit is called "***geosynchronous***" or "***geostationary”*** or***GEO.*** If in addition it were orbiting over the equator, it would appear, to an observer on the earth, to stand still in the sky. Raising a satellite to such an altitude, however, requires still more rocket boost, so that the achievement of a geosynchronous orbit did not take place until 1963.

America in 1960, launched the first simple communications satellite called Echo Satellite because it consisted only of a large (100 feet in diameter) aluminized plastic balloon. Radio and TV signals transmitted to the satellite would be reflected back to earth and could be received by any station within view of the satellite. Unfortunately, Echo Satellite is LEO which appears briefly every 90 minutes – a serious impediment to real communications.

The solution to this problem lay in the use of the geosynchronous orbit. In 1963, the necessary rocket booster power was available for the first time and the first geosynchronous satellite , Syncom 2, was launched by NASA. For those who could "see" it, the satellite was available 100% of the time, 24 hours a day. The satellite could view approximately 42% of the earth. For those outside of that viewing area, the satellite was never available. The one disadvantage of the geosynchronous orbit is that the time to transmit a signal from earth to the satellite and back is approximately ¼ of a second - the time required to travel 22,300 miles up and 22,300 miles back down at the speed of light. For telephone conversations, this delay can sometimes be annoying. For data transmission and most other uses it is not significant. In any event, once Syncom had demonstrated the technology necessary to launch a geosynchronous satellite, a virtual explosion of such satellites followed. Today, there are approximately 150 communications satellites in orbit, with over 100 in geosynchronous orbit where NIGCOMSAT-1 is placed.

Every communications satellite in its simplest form (whether LEO or geosynchronous) involves the transmission of information from an originating ground station to the satellite (the uplink), followed by a retransmission of the information from the satellite back to the ground (the downlink). The downlink may either be to a select number of ground stations or it may be *broadcast* to everyone in a large area. Hence the satellite must have a receiver and a receive antenna, a transmitter and a transmit antenna, some method for connecting the uplink to the downlink for retransmission, and prime electrical power (usually solar panels) to run all of the electronics and provide the power for retransmission. The exact nature of these components will differ, depending on the orbit and the system architecture, but every communications satellite must have these basic components shown in Fig.1.

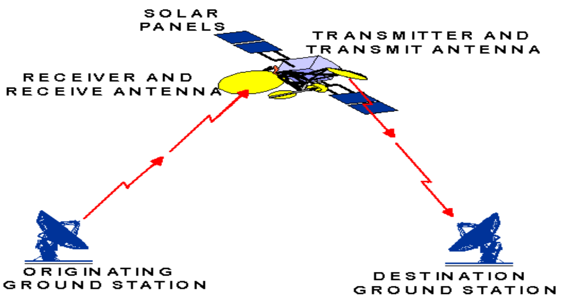

Fig.1 Basic Components of NIGCOMSAT-1 Link

The amount of power which a satellite transmitter needs depends on its orbit. The geosynchronous satellite is at an altitude of 22,300 miles, while the LEO satellite is only a few hundred miles. The geosynchronous satellite is nearly 100 times as far away as the LEO satellite. It is a simple matter to show that the GEO satellite would need almost 10,000 times as much power as the LEO, if everything else were the same. (Fortunately, of course, we change some other things so that we don't need 10,000 times as much power.)

2.2 SATELLITE ANTENNAS

One of the biggest differences between a LEO and a GEO satellites is in their antennas. As mentioned earlier, the geosynchronous satellite would require nearly 10,000 times more transmitter power, if all other components were the same. One of the most straightforward ways to make up the difference, however, is through antenna design. Virtually all antennas in use today radiate energy preferentially in some direction. An antenna used by a commercial terrestrial radio station, for example, is trying to reach people to the north, south, east, and west. However, the commercial station will use an antenna that radiates very little power straight up or straight down. Since they have very few listeners in those directions (except maybe for coal miners and passing airplanes) power sent out in those directions would be totally wasted.

The communications satellite carries this principle even further. All of its listeners are located in an even smaller area, and a properly designed antenna will concentrate most of the transmitter power within that area, wasting none in directions where there are no listeners. The easiest way to do this is simply to make the antenna larger. Doubling the diameter of a reflector antenna (a big "dish") will reduce the area of the beam spot to one fourth of what it would be with a smaller reflector. We describe this in terms of the *gain* of the antenna. Gain simply tells us how much more power will fall on 1 square centimeter (or square meter or square mile) with one antenna than would fall on another if the transmitter power were spread uniformly (isotropically) over all directions. The larger antenna described above would have four times the gain of the smaller one. This is one of the primary ways that the geosynchronous satellite makes up for the apparently larger transmitter power which it requires.

Another big difference between the geosynchronous antenna and the LEO antenna is the difficulty of meeting the requirement that the satellite antennas always be "pointed" at the earth. For the geosynchronous satellite, of course, it is relatively easy. As seen from the earth station, the satellite never appears to move any significant distance. As seen from the satellite, the earth station never appears to move. We only need to maintain the *orientation* of the satellite. The LEO satellite, on the other hand, as seen from the ground is continuously moving. It zooms across our field of view in 5 or 10 minutes.

Likewise, the earth station, as seen from the satellite is a moving target. As a result, both the earth station and the satellite need some sort of tracking capability which will allow its antennas to follow the target during the time that it is visible. The only alternative is to make that antenna beam so wide that the intended receiver (or transmitter) is always within it. Of course, making the beam spot larger decreases the antenna gain as the available power is spread over a larger area , which in turn increases the amount of power which the transmitter must provide.

2.3. Modern Satellite Development – The ACTS

The current trend in communications satellite systems development depends on the demands of the marketplace (direct home distribution of entertainment, data transfers between businesses, telephone traffic, cellular telephone traffic, etc.); the costs of manufacturing, launching, and operating various satellite configurations; and the costs and capabilities of competing systems - especially fibre optic cables, which can carry a huge number of telephone conversations or television channels.

The new trend includes NASA's Advanced Communications Technology Satellite (ACTS) which consists of a relatively large geosynchronous satellite with many uplink beams and many downlink beams, each of which covers a rather small spot (several hundred miles across) on the earth. However, many of the beams are "steerable". That is to say, the beams can be moved to a different spot on the earth in a matter of milliseconds, so that one beam provides uplink or downlink service to a number of locations. Moving the beams in a regular scheduled manner allows the satellite to gather uplink traffic from a number of locations, store it on board, and then transmit it back to earth when a downlink beam comes to rest on the intended destination. The speed at which the traffic is routed and the agility with which the beams move make the momentary storage and routing virtually invisible to the user. The ACTS satellite is also unique in that it operates at frequencies of 30 GHz on the uplink and 20 GHz on the downlink. It is one of the first systems to demonstrate and test such high frequencies for satellite communications.

The use of high data rate (HDR) communications, especially of synchronous digital hierarchy has significantly reduced satellite antenna sizes with optimal efficiency and gain. HDR transmissions, especially synchronous digital hierarchy of 155 Mbits/sec or faster, also facilitates Satellite to terrestrial connectivity via optic fibre cables. Thus Satellites could play a vital role in supercomputer networking such as GLOBUS, HDTV distribution, and in broadband ISDN (B-ISDN) networks.

2.4. NIGCOMSAT-1

Nigcomsat-1 was put into the geosynchronous orbit by the China Great Walls Industry that won the contract for the design, building and launching of the Satellite for Nigeria. NIGCOMSAT-1 (Fig.1) is a super hybrid geo-stationary satellite designed to operate in C, Ku, Ka and L bands with footprints over Africa, part of Middle East and southern Europe and intended to meet most of the ICT needs of Africa. China manufactureed NIGCOMSAT-1 developed on the base of dongfang-h4 (DFH-4) satellite bus to meet Nigeria's needs in the fields of telecommunication, broadcast, broadband multimedia, telemedicine, distance education etc. Compared with first and second generation satellites, DFH-4 is featured by large output power, powerful payload capacity and long life span, over 15 years. The overall performance of the satellite reaches the international advanced level of the same type of communications satellite, with reliability of better than 0.70. NIGCOMSAT-1 is the first Nigerian and African Communications Satellite in the geosynchronous orbit, at 42°E, with payload of 40 transponders [4].

The basic mechanism of transmission and reception via a satellite for any application is shown in Fig.1. It could be some lectures from a distant professor being broadcast,it could be a television broadcast from a TV station being transmitted to distant viewers and so on.

2.5 TRANSPONDER

In the field of telecommunications, the term **transponder** (short-for *Trans*mitter-res*ponder* and sometimes abbreviated to XPDR, XPNDR or TPDR) may be described as:

- An automatic device that receives, amplifies, and retransmits a signal on a different frequency band.
- An automatic device that transmits a predetermined message in response to a predefined received signal.
- A receiver-transmitter that will generate a reply signal upon proper electronic interrogation.

Original analog video has only one channel per transponder, with subcarriers for audio and automatic transmission identification service (ATIS). Non-multiplexed radio stations can also travel in single channel per carrier (SCPC) mode, with multiple carriers (analog or digital) per transponder. This allows each station to transmit directly to the satellite, rather than paying for a whole transponder, or using landlines to send it to an earth station for multiplexing with other stations.

3. Healthcare Delivery through NIGCOMSAT-1

An example of Telemedicine application of NIGCOMSAT-1 is in the multipurpose healthcare delivery system whichhas been designed [5],[8],[9] and consists of a base unit and a telemedicine unit where the integrated system:

• Can be used when handling emergency cases in ambulances, remote locations, RHC or ships by using the Telemedicine unit at the emergency or remote sites and the expert's medical consulting at the base unit

• Enhances intensive health care provision by giving the telemedicine unit to the ICU doctor while the base unit is incorporated with the ICU's in-house telemetry system

• Enables home tele-monitoring, by installing the telemedicine unit at the patient's home, especially for patients suffering from chronic and /or permanent diseases (like heart disease or cancer), while the base unit remains at the physician's office or hospital.

It is able to transmit bio-signals such as both 3 and 12 lead ECGs, vital signs (non-invasive blood pressure, temperature, heart rate, oxygen saturation and invasive blood pressure), and still images of a patient by using a great variety of communication means (Satellite, GSM and Plain Old Telephone System – POTS). The base unit is comprised of a set of user-friendly software modules that can receive data from the Telemedicine device, transmit information back to it and store all data in a database at the base unit. The communication between the two parts is based on the TCP/IP technology.

Figure 2 describes the overall system architecture. In each different application, the Telemedicine unit is located at the patient's site, whereas the base unit (or doctor's unit) is located at the place where the signals and images of the patient are sent and monitored.

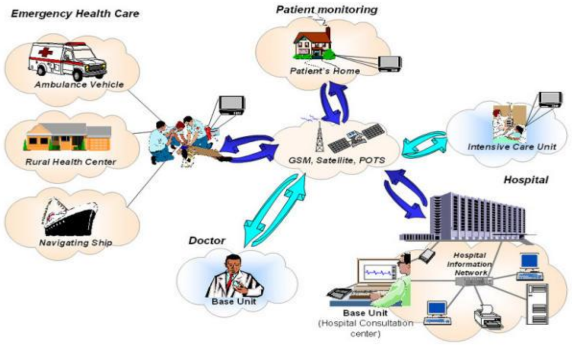

Fig. 2. Overall System Architecture for a Multipurpose telemedicine

The Healthcare delivery device is responsible to collect data (bio-signals and images) from the patient and automatically transmit them to the base unit (Doctor's location). The base unit is comprised of a set of user-friendly software modules, which can receive data from the Telemedicine device, transmit information back to it and store important data in a local database. The system has several different applications (with small changes each time), according to the current healthcare provision nature and needs. The information flow (using a layered description) between the two sites can be seen in Figure 3

The bio-signals collected from the patient (and then transmitted to the Base Unit) are:

• ECG up to 12 lead, depending on the monitor used in each case.

• Oxygen Saturation (SpO2).

• Heart Rate (HR).

• Non-Invasive Blood Pressure (NIBP).

• Invasive blood Pressure (IP).

• Temperature (Temp)

• Respiration (Resp)

The control of the Telemedicine unit is fully automatic [9],[10]. The only thing the telemedicine unit user has to do is connect the bio-signal monitor to the patient and turn on the PC. The PC then performs the connection to the base unit automatically [11],[12].

Through the base unit, user has the full control

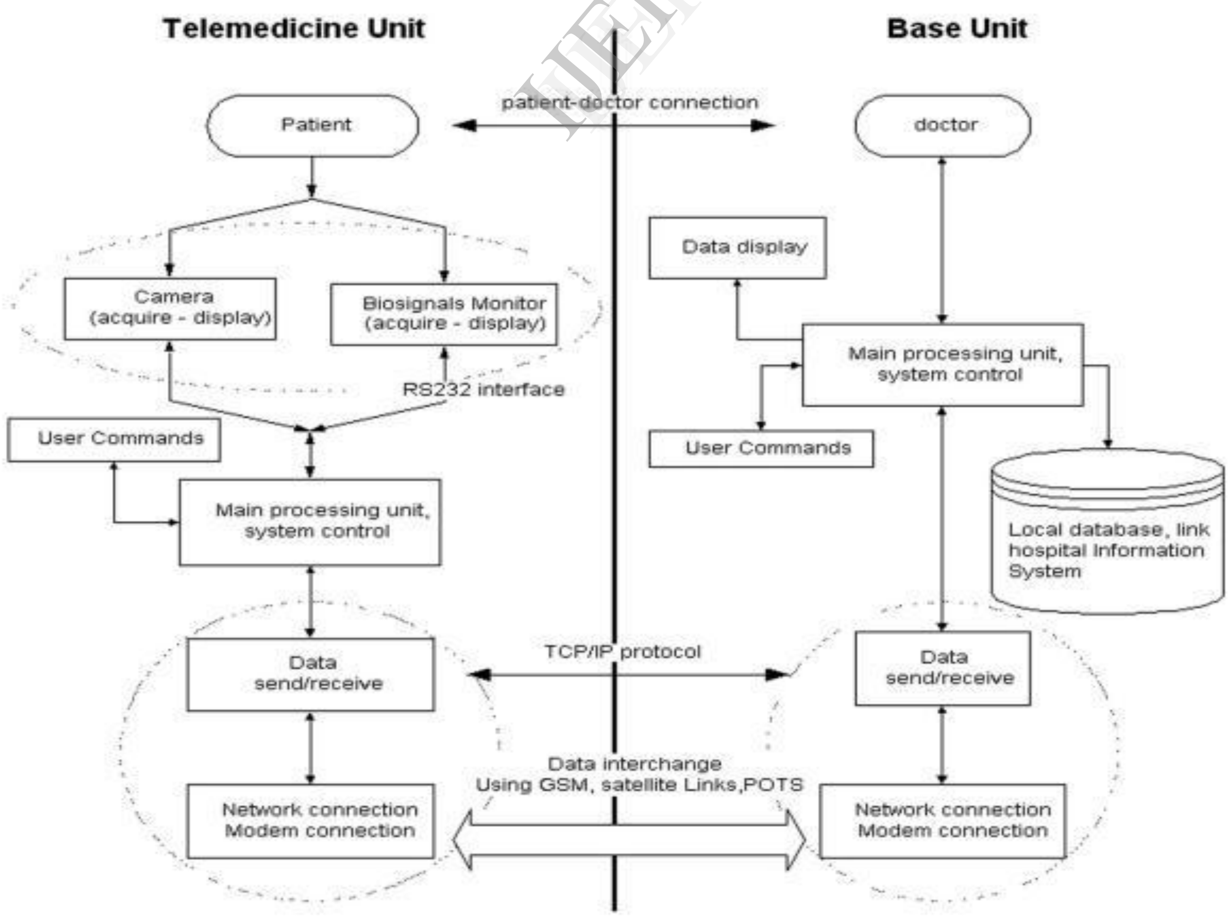

Fig. 3. Information Flow within the Telemedicine system (Telemedicine and base units)

of the telemedicine session. The user is able to monitor the connection with a client (telemedicine unit), send commands to the telemedicine unit such as the operation mode (bio-signals or images). In cases were the base station is connected to a Hospital LAN the user can choose to which of the telemedicine units to connect to, as shown in Figure 5 the user of the base unit is able to choose and connect to anyone of the telemedicine units connected on the network.

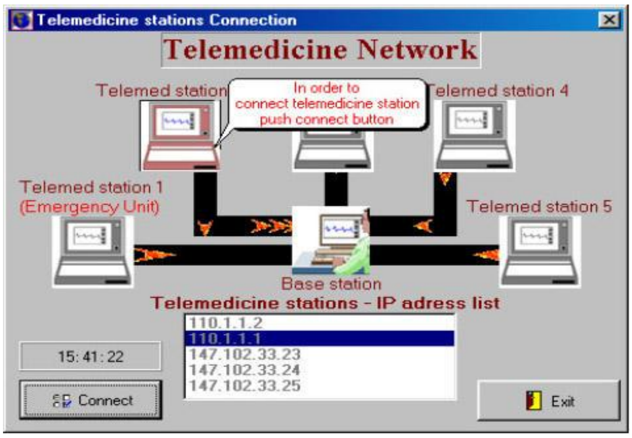

Fig. 4 Telemedicine Network Control - Base Unit

The Base Unit's user can monitor bio-signals or still images coming from the Telemedicine unit, thus keeping a continuous online communication with the patient site.

When the Base Unit is located in a hospital (especially in emergency handling or in home telecare), a Hospital database unit can be integrated in the system, in order to record information concerning the cases handled.

In cases where a Hospital Information System (HIS) is already available at the Base Unit site (Hospital), the doctor (Base Unit user) can retrieve information (using the hospital archiving unit) concerning the patient's medical history. When HIS is not available, the Hospital Database Unit can handle the patient medical record by itself.

3.1. Use of NIGCOMSAT-1 as a Communication Medium

The first Nigeria's Communication Satellite, NIGCOMSAT-1 will provide efficient and cost effective medium of data and image transmission between the Telemedicine unit and the Base unit. The Telemedicine unit located in remote areas such as the Niger Delta swamps, rural healthcare centres, navigating ships or homes in the mountainous regions can transmit biosignals and patient images to NIGCOMSAT-1 which has various transponders, one of which may be dedicated for national healthcare telemedicine. NIGCOMSAT-1 will thus receive and retransmit these signals via the transponder to the base station where the expert doctors in specialist hospitals, whether in Nigeria or abroad, is located.

The advantages of NIGCOMSAT-1 over other communication media such as GSM or Plain Old telephony system (POTS) are: 1. its ability to transmit large volumes of data and image signals and 2. its ability to serve the remotest part of Nigeria where neither the GSM masts nor the POTS cables could reach.

NIGCOMSAT-1 shall therefore remain the primary backbone for e-healthcare telemedicine in Nigeria and other parts of Africa. The expected bandwidth performance of about 1.5Mbps in both upstream and downstream, places NICOMSAT-1 in the state of the art position as the veritable tool for compressed video images, audio and data transmission with maximum efficiency.

4 CONCLUSION

We have seen that NIGCOMSAT-1, a super hybrid geo-stationary satellite designed to operate in wide frequency bands shall indeed meet most of the current and future communications needs of Nigeria and Africa, especially in Healthcare deliveryamong others. Since this will mobilise Nigerian Universities for collaborative work in Satellite Technology, a simplified background of Communications Satellites and components that will encourage even the beginners to venture into this field was given. In modern Satellite Communications development such as NIGCOMSAT-1, the use of steerable beams provides uplink and downlink services to a number of locations making it possible for many locations in Nigeria and Africa to be served by NIGCOMSAT-1.

HDR transmissions, especially synchronous digital hierarchy of 155 Mbits/sec or faster, will also facilitate Satellite to terrestrial connectivity via optic fibre cables. Thus Satellites could play a vital role in supercomputer networking. HDTV distribution, and in broadband ISDN (B-ISDN) networks.

NIGCOMSAT-1 will find useful applications in the multipurpose healthcare telemedicine system that would provide expert healthcare and home tele-monitoring even to remotest parts of Nigeria and Africa. The broadband transmission channel required to transfer large volumes of data and high resolution images is provided by NIGCOMSAT-1.

NIGCOMSAT-1,is therefore of enamours benefit to Nigeria in particular and Africa in general, especially in e-Healthcare delivery.

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